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ABSTRACT

Statistics forms the backbone of many undergraduate and graduate courses in education and psychology, however, many students find it difficult to master. Information technology can help these students' difficulties with statistics in two ways: it can be used to reduce the drudgery associated with large amounts of calculation; and it can be used to support the teaching of basic concepts in statistics in a more illuminating and motivating way. This paper looks at two different programs and illustrates how the use of particular computer-based activities contributed to students' understanding of statistical concepts. The paper looks at findings from evaluation studies of the systems "Link" (Morris, 1997) and "ActivStats" (Morris & Scanlon, 1999). "Link" is an application designed to address students' difficulties concerning the topic of correlation, and "ActivStats" is a multimedia learning resource for teaching statistics across a range of disciplines. Each of the cases highlights a particular feature of the program design which is likely to influence students' learning of statistics. (Contains 16 references.) (AEF)

Design Features in Computer Supported Learning Environments for Teaching Statistics to Psychology Students

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Design features in computer supported learning environments for teaching statistics to psychology students

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Introduction

While statistics is a difficult subject for students it forms the backbone of many undergraduate and graduate courses in education and psychology. There are a variety of interrelated reasons why students taking such courses might find statistics difficult to master. For example, inadequacies in prerequisite mathematical skills may hinder students learning statistical concepts and techniques. Research has focused on students' misconceptions that impede the acquisition of statistical concepts (Garfield & Ahlgren, 1988), and it is argued that these misconceptions are prevalent, persistent and resistant to traditional forms of instruction (Cumming & Thomason, 1995). The statistical curriculum is changing with the increasing use of computers in higher education (Hawkins, Jolliffe & Glickman, 1992) where, for example, students use data-analysis software, such as SPSS for the analysis of data sets and do not therefore have to compute statistics with the aid of a calculator and a prescribed procedure that is outlined in a text. Computer-supported learning environments, which are designed to impart statistical concepts, can also be used as part of a statistics curriculum to provide an alternative form of instruction where linked multiple representations and simulations can be used to address students' misconceptions in statistics, and more obviously, enable students to learn at their chosen pace. Interactive simulations might contribute to students' understanding by, for example, influencing students towards a normative view of some statistical concepts (e.g., Shaughnessy, 1992).

Reviews of the potential features of computer-based learning environments for statistics provides the following list of desirable design features (Morris, in press; Morris & Le Voi, 1998; see also Scanlon & O'Shea, 1998):

- Dynamically linked multiple representations.
- Learner activities designed to address students' prior conceptions.
- Presentations of concepts in realistic contexts.
- Simulations that allow the learner to experiment with concepts.
- Feedback to learner activities that are contingent on the student's responses.

In summary, information technology can help students' difficulties with statistics in two ways: it can be used to reduce the drudgery associated with large amounts of calculation, but more importantly, it can be used to support the teaching of basic concepts in statistics in a more illuminating and motivating way. In this paper, we look at two different programs and illustrate how the use of particular computer-based activities contributed to students' understanding of statistical concepts.

Case studies

In this paper we look at findings from evaluation studies of the systems *Link* (Morris, 1997) and *ActivStats* (Morris & Scanlon, 1999). These qualitative findings illustrate how computer-supported learning environments might help students with basic concepts in statistics. First, we will outline the design and testing of *Link*, which is an application that was designed to address students' difficulties concerning the topic of correlation, and was constructed at the Open University, UK (Morris, in press). The design of *Link* was informed by research-based principles of learning and empirical work on students' understanding of correlation. Second, *ActivStats* is a multimedia learning resource for teaching statistics across a range of disciplines (*ActivStats*, 1997). These two case studies are illustrative of the different ways in which learning environments can enhance student learning of statistics, and the way that data on students' misconceptions can be addressed by designers of teaching materials for statistics.

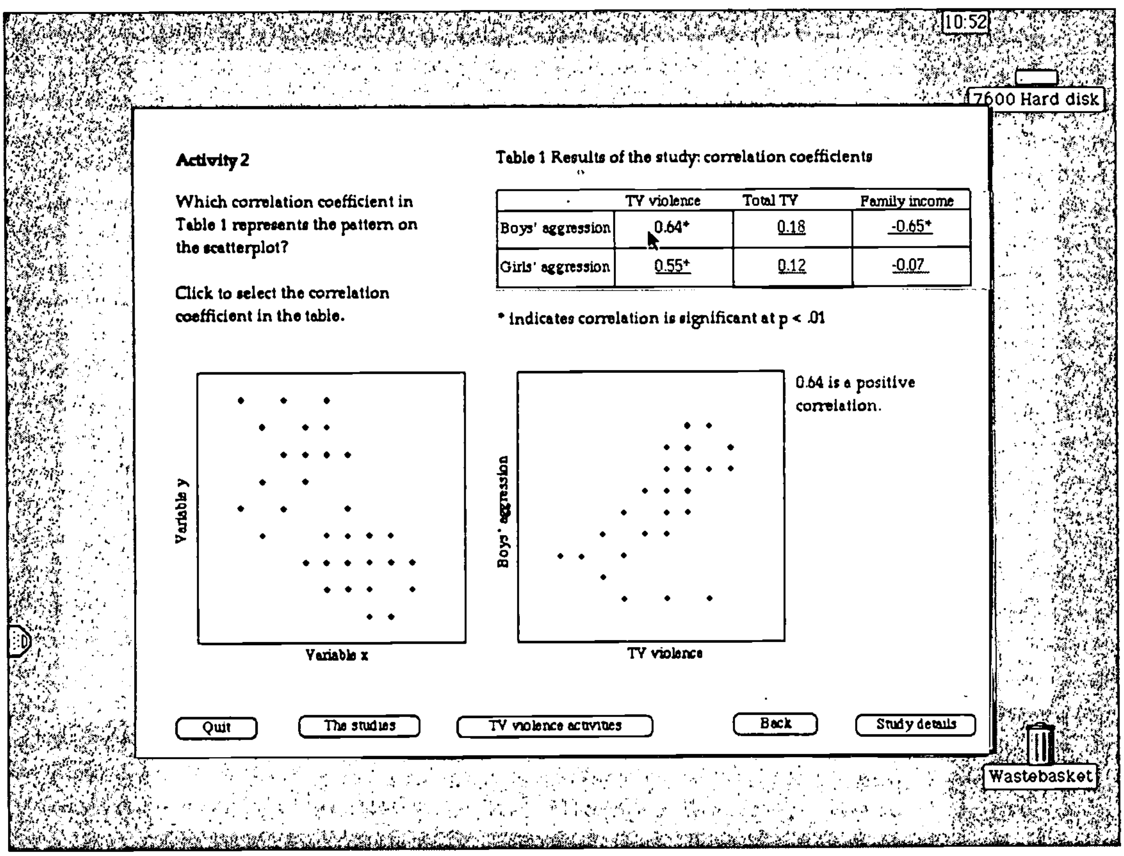
Link

Link is a Macromedia Director application that was designed to be used by students who are taking undergraduate degree programmes in psychology and who have already studied the topic of correlation. Through using *Link* students can review their understanding of correlation by completing learner activities that were specifically developed to address students' misconceptions concerning correlation. It has been shown in previous research (Estepa & Batanero, 1996; Morris, 1999) that some students inappropriately infer causality from correlation, and are confused by negative correlations and the strength of correlations. More specifically, a student may hold a unidirectional conception of correlation where they assume that a correlation is positive or that a negative correlation indicates no correlation between variables. A student might also think that a positive correlation coefficient is stronger than a negative correlation coefficient when this is not the case (Morris, 1999).

The teaching material in *Link* is presented in the context of studies that make use of genuine data from research studies in psychology which were conducted at the Open University. In *Link*, learners activities are provided in the context of these psychology studies, which are described in the program, and the activities use data in the form of correlations between variables and scatter plots. For example, a data set from a study of memory for medical history was used in the final version of the program (Cohen & Java, 1995).

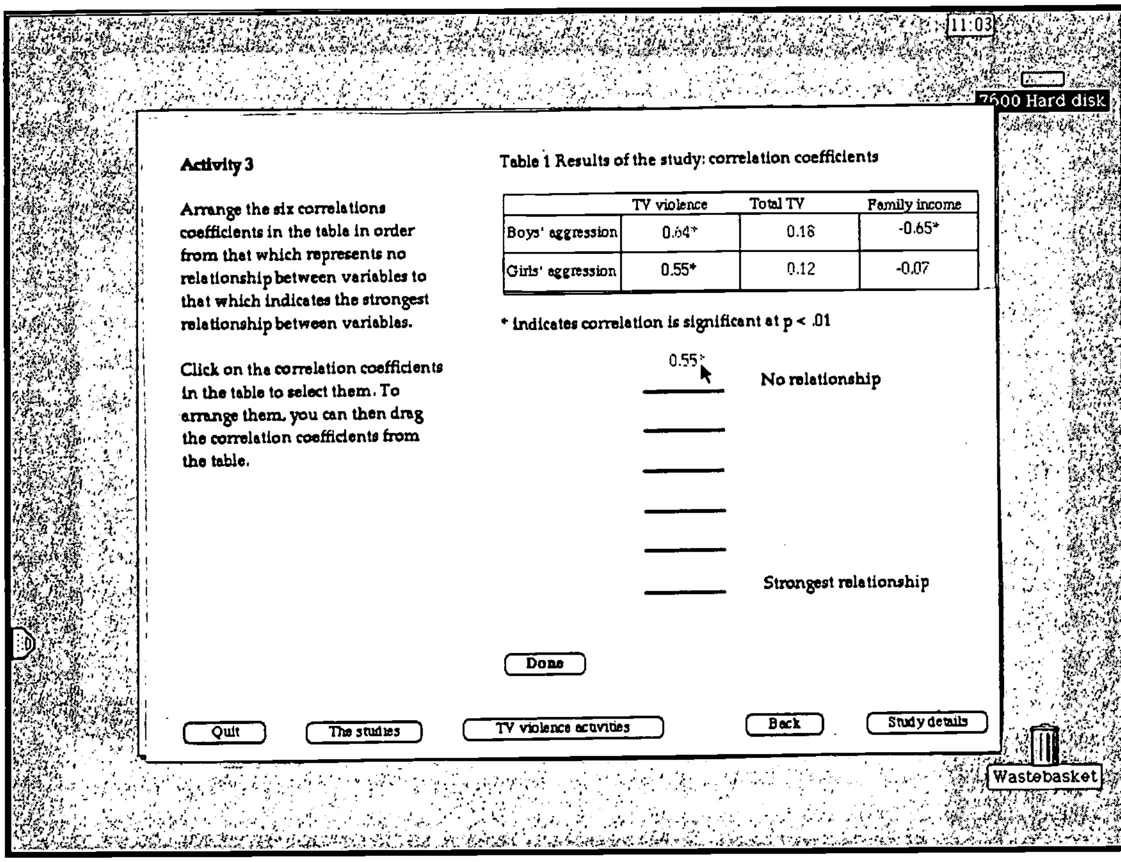
One of the learner activities was designed to address a unidirectional conception of correlation and makes use of data in the form of correlations presented in a table (figure 1). On this activity, students are not told that the scatter plot that is presented on the screen represents a negative correlation, rather, they are asked to decide which correlation in the table represents the pattern on this scatter plot. If a student were to select 0.64 in the table, a scatter plot showing this positive correlation would be displayed alongside the target scatter plot and the student would be provided with appropriate feedback. The student can select any of the correlations in the table and the appropriate scatter plot and associated feedback is displayed. The strategy used in this activity is similar to a suggested teaching strategy: 'differentiation of a conception' (Driver, 1988). A student might hold a unidirectional conception of correlation, which means that their conception of correlation is global and ill-defined, and certain experiences are necessary to ensure that they differentiate their conception. Through activity 2 a student would not only see that a correlation can indicate a negative relationship between two variables, but they would also have the opportunity to view a negative correlation on a scatter plot compared with, for example, the pattern of a positive correlation and/or a pattern that indicates no relationship between variables.

Figure 1. *Link*: activity 2



Another learner activity in *Link* was designed to address the conception in which students think a positive correlation of say, 0.80 is stronger than a negative correlation of say, -0.90 (figure 2). In this activity, the student can drag correlation coefficients from a table of data to arrange them in the appropriate sequence. This activity involves students selecting the coefficients in the table and dragging them to arrange them in an order from that which represents the weakest relationship to that which indicates the strongest relationship between variables. When a student has completed this task, they are provided with feedback that is appropriate in terms of their arrangement of the set of correlations. *Link* also provides activities that have been designed to address a student's causalistic conception of correlation.

Figure 2. *Link*: activity 3



Findings from a formative evaluation study of a prototype of *Link*, indicated that students' use of linked multiple representations affected their understanding of correlation (Morris, 1997). The findings that concern students working with the program are described with respect to activity 2 and activity 3 that students completed.

For learner activity 2 students were expected to select the coefficient in the table (-0.65) that represented the target scatter plot that was displayed on the screen. From observing students using *Link*, a variety of approaches to activity 2 were recorded. At the beginning of the activity, out of a total of eighteen students who participated in the formative evaluation study (Morris, 1997), four students appeared not to be able to initially attempt the activity, but they then completed it and worked out that the negative correlation of -0.65 represented the scatter plot in question. For example, one of these students said "I'm puzzled. I'm afraid" and was prompted to select a correlation as instructed by the program. She selected the correlation 0.64, and then commented "Oh no, so it's the other way" and selected the correlation -0.65. Another student approached the activity in a similar way. Initially, this student remarked "don't like these scatter graphs" and went on to say that she could not "picture it in a graph form like that." This participant then said she would guess and selected the correlation 0.64 and said "so that's [a] positive correlation" and "so we need a negative correlation" and she then selected -0.65. This student did, however, comment further "I have to say I still don't understand why it represents what it says it does on the graph." In completing activity 2, one student commented "I haven't the first idea ... I'm completely lost here ... I could have a guess", but then selected the positive correlation 0.55 in the table. Accordingly, a scatter plot that represents this coefficient was displayed on the screen and this student said "in that case it must be that I looking for a negative correlation" and selected -0.65. He then, however, added "that's not a bad guess second time ... I'm not familiar with scatter plots." One student could not understand the question that accompanies activity 2, and initially remarked "I have no idea what that means", and "how can one figure become a complete graph." With reference to the target scatter plot, this student commented "there's no pattern there at all as far as I can see" and "not much of one anyway." The student was prompted to select a correlation coefficient in the table and he clicked with the mouse on 0.64. Accordingly, feedback that read '0.64 is a positive correlation' and a scatter plot that represented this relationship was displayed on the screen and this participant then commented "positive correlation. So that goes that way" and "must be a minus one but just in the middle" and "so I'm going to go for double 0 7 [-0.07]." The participant then selected the correlation -0.07 in the table and said "well that's quite close" before he selected the correlation -0.65.

In the formative evaluation of *Link*, it was found that thirteen out of the eighteen students involved in the study, successfully completed activity 3 by selecting the correlation coefficients with the mouse and dragging them from the table and arranging them on the screen in the appropriate order. When completing this activity, one of these students remarked "I can't remember if I've got this right or not." Having read the text for the activity, one student commented "my initial instinct is to go with the lowest and move upwards ... I know that 64, 55, 65 [0.64, 0.55, 0.64] are significant ... So that must make ... a strong relationship between the variables." She then went on to say "I'm quite put off by -0.07 ... just because it's ... a long way away quite along way the other way that it's quite a strong relationship but it's not necessarily a positive one ... but it's not significant." Although this participant arranged the correlations in the correct order she commented "I'm just going to put them in order numerical order. ... Unless something else comes to me."

As part of the formative evaluation study, students were asked on a questionnaire what they thought of activity 2 in the program. One student thought that it was a "good exercise in interpreting scatter plots and relating them to coefficients", and another student noted "useful to check your understanding of both modes of presenting the figures." One student wrote that this activity was "interesting for someone learning statistics so he or she can picture the relationship between the scatter plot and the correlation coefficient", and another student's comments read "very useful to grasp the idea of how, visually, coefficients should be." One student pointed out that although he made an error on this activity "it was very matter-of-fact in its correction and led me easily to the correct answer."

Students were also asked what they thought of activity 3 in the program. Here, students evidently liked selecting and dragging correlations across the screen:

"It interested me that I could move the results. It made me feel I was being tested on my understanding of correlation."
"I liked the click-and-drag feature, especially being able to reverse a choice easily. maybe it could have mentioned this latter fact."
"Good - nice to manipulate objects around the screen."
"I found this the most useful activity."

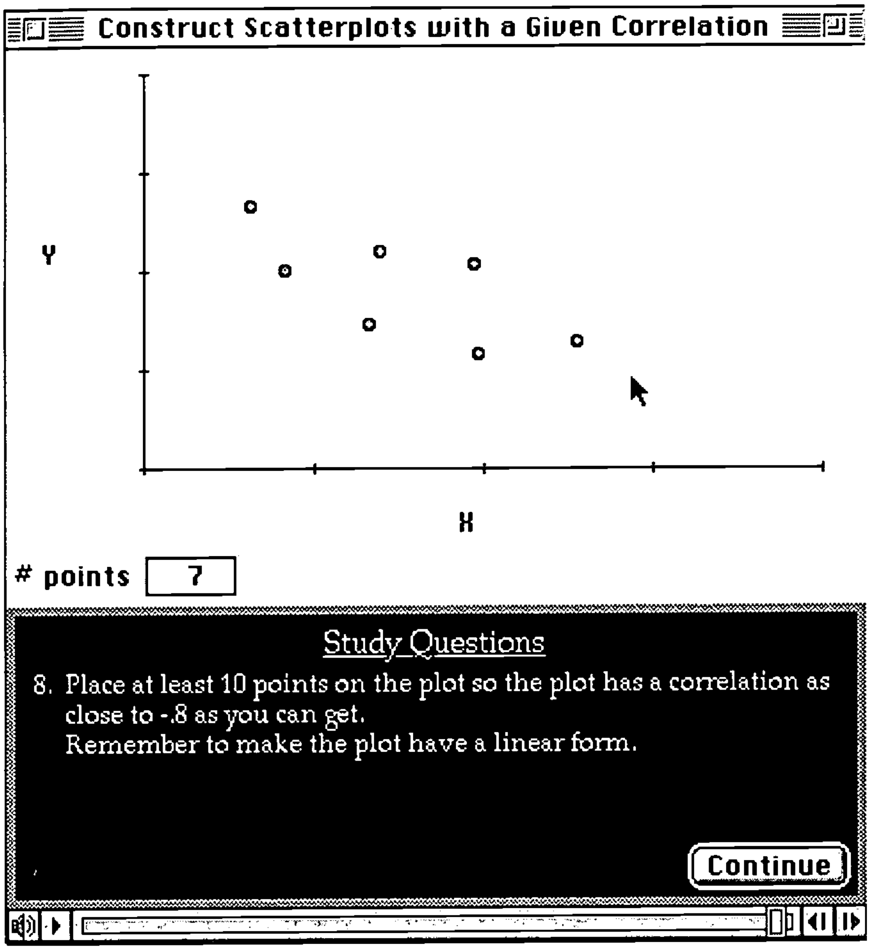
We have presented here an example of how instruction based on the diagnosis of students' misconceptions can help students learning about correlation. Further information is given Morris (in press).

ActivStats

ActivStats is a multimedia resource for learning statistics which uses the metaphor of a Lesson Book to provide video, text, graphics and learners activities (*ActivStats*, 1997). It provides both a resource to teach statistical concepts and techniques, and data-analysis software. Our data collection focused on a subset of learner activities concerning correlation.

In an in-depth qualitative study, pairs of students working collaboratively were observed while they completed these learner activities. It was found that one of the learner activities in particular, enabled students to see the effect that outliers have on the value of a correlation (Morris & Scanlon, 1999). On this activity students had the opportunity to construct scatter plots at the interface and by dragging various data points could view the corresponding change in the value of a correlation coefficient. On this activity, students were also asked to build scatter plots for a particular value of a correlation without initially being able to view the value of that relationship. Students were asked to construct scatter plots of 0.5 and -0.8 without seeing the value of the correlation, and when they constructed the scatter plot in these cases they could then select a button 'Continue' to obtain the value of the correlation (figure 3).

Figure 3. A learner activity from *ActivStats*



One pair of students (D and A) attempted to construct scatter plots with correlations of 0.5 and -0.8 without being able to view the correlations. In such a case, the following observations were made:

D attempted to construct a scatter plot with a correlation of 0.5.
A remarked "Careful not to do too straight line."
A placed 10 data points on the scatter plot.
D "Okay. What do you reckon?"
A "Must be close."
D obtained the value 0.731.
Alan commented "Oh it's too positive."
D read the screen that stated "You can get closer. Try again."
A then attempted to construct a scatter plot with a correlation of 0.5, but obtained a correlation of 0.6.
D remarked "Closer."
D then had another attempt at constructing a scatter plot with a correlation of 0.5, but obtained a correlation of 0.8.
A also had a second attempt at constructing a scatter plot with a correlation of 0.5 and obtained a correlation of 0.512.
D commented "Oh. Well done. Excellent.
D tried to obtain a correlation of -0.8, but obtained -0.917.
A "Close, very close."
A then tried to obtain a correlation of -0.8 and got a correlation of -0.764.
D responded by saying "Close" and he had a second attempt at the correlation -0.8.
D obtained a correlation of -0.791 and commented "Yes ... That was more luck than judgement."

In general, the findings of the qualitative study indicated that in terms of learning, students found it valuable to construct scatter plots that were dynamically linked to a correlation. In addition, this kind of linked representation allowed students to see that outliers or isolated points can have an influence on a correlation (Morris & Scanlon, 1999).

Review

Each case study illustrates a particular way in which an interactive learning environment can contribute to students' understanding of statistical concepts. In each of the cases we have highlighted a particular feature of the program design, which is likely to influence students learning of statistics.

In the case of *Link*, learner activities are provided in the context of real studies from psychological research, and these activities were designed to help students' difficulties concerning negative correlations and the strength of correlations. It should be emphasised that psychology students must not only come to understand the concepts relating to correlation, but must also learn to interpret correlations in the context of psychological research. For example, students should be able to make sense of the findings from a study that employs a correlational design and be able to contemplate possible explanations of reported relationships between variables. Statistics textbooks aimed at psychology students typically present neat and tidy relationships, which have coefficients of zero, -1, or 1, (or near such values) and are illustrated by scatter plots (e.g., Gravetter & Wallnau, 1995). Authentic data sets from research do not tend to be used in this context. In the case of computer-based learning materials that cover correlation, real data sets from the psychological research literature have not typically been used (Morris, 1999). However, constructivist approaches to learning have emphasised that concepts to be acquired by a learner should be presented in a realistic and meaningful context (e.g., Bransford et al, 1990). Real data from psychological research can produce correlations that are near to 0.4 or 0.3, which if plotted give rather untidy scatter plots. In contrast to the majority of existing computer-based learning materials, *Link* makes use of data sets from authentic research studies and therefore provides learners with a variety of different kinds of real relationships. In the case of *ActivStats*, students were given the opportunity to construct scatter plots and to see the impact of plotting and dragging data points on the corresponding value of a correlation. Observational data indicated that students valued these dynamically linked representations.

One similarity of the case studies is that the students tended to engage in the computer-based learner activities and therefore produce results that they needed to interpret. We have not explored in detail here the possible role that feedback can play in students' learning. However, in each case feedback is provided to students' responses to the learner activities and their actions. For example, in an activity we described from *Link*, student feedback is given in the form of a scatter plot and text that describes what kind of relationship is represented by the correlation. In the *ActivStats* learner activity, students obtained feedback in terms of comparing their result to the desired numerical result and also by directly manipulating the objects in the representation. We need to ask how students interpret the tasks they are being asked to undertake here, particularly what impact the different contexts have on student behavior and understanding. The use of realistic data in *Link* allowed us to present students with the type of scatter plots they are likely to experience in their own future work in psychology.

Conclusions

Computers can support a range of styles of teaching and learning. In this paper we have concentrated on examining ways in which the properties of the computer can be harnessed to help students come to understand the difficult ideas in statistics. Instruction in statistics should not ignore the contexts in which statistical knowledge is applied and in consequence, we have reported here on two cases of computer-supported learning environments that could be used by psychology students. We have cited the positive outcomes of computer-based learning materials that present concepts in realistic contexts, use linked multiple representations and are designed to address students' prior conceptions.

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